Astronomy 191 - Stars

- Examples & Definition
- Observables
- Physical Processes

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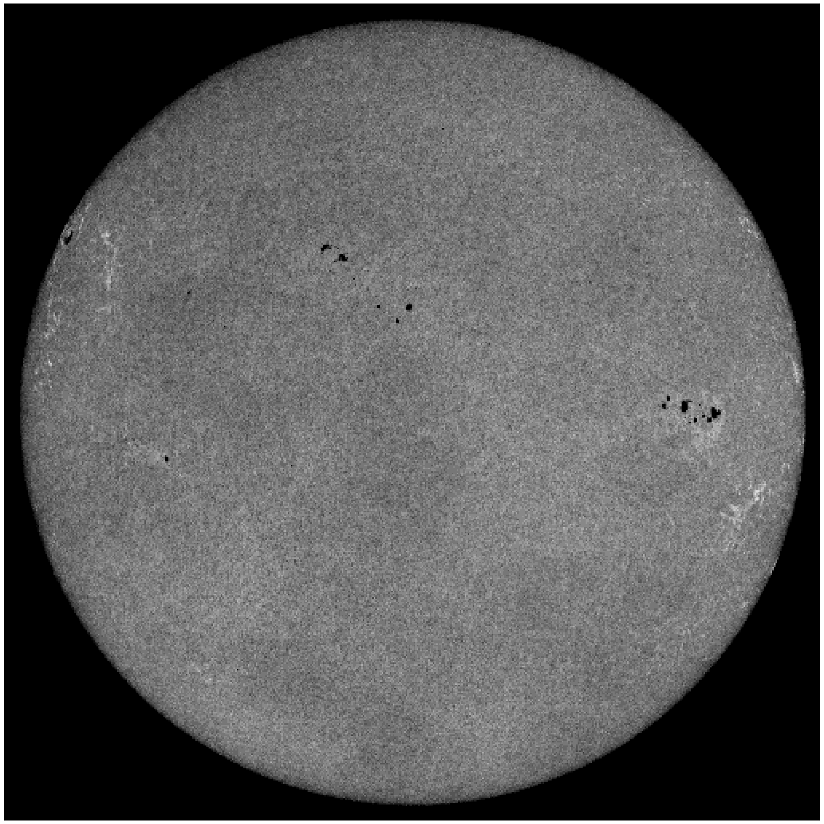
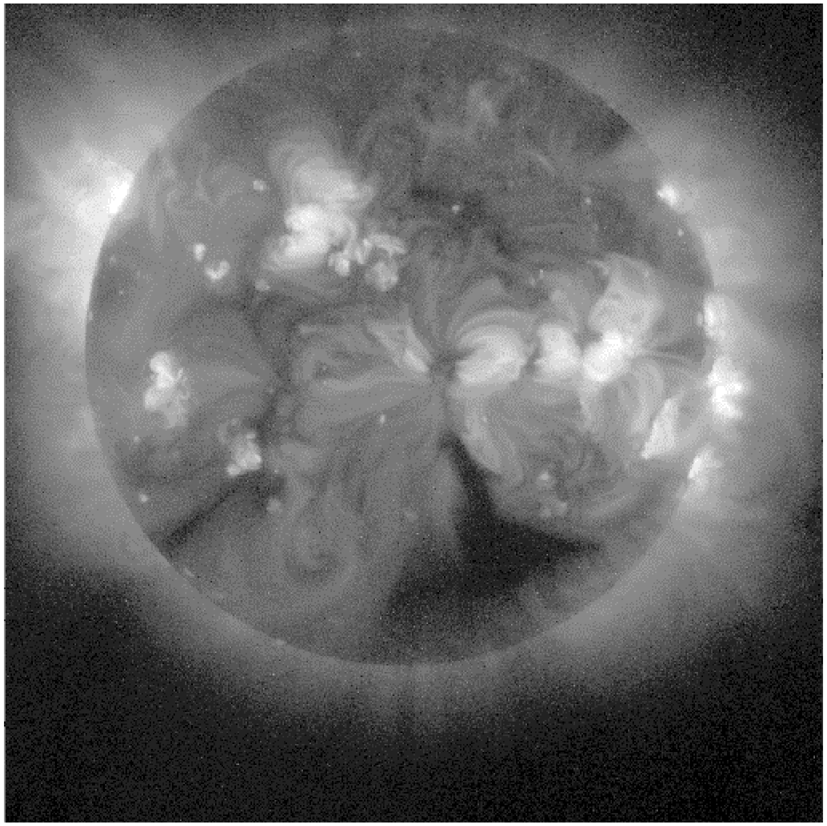
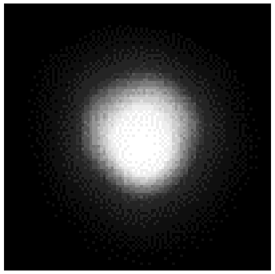


The Sun on Jan 30, 2001, white light (SOHO)



The Sun on Jan 30, 2001, X-ray image (Yohkoh)

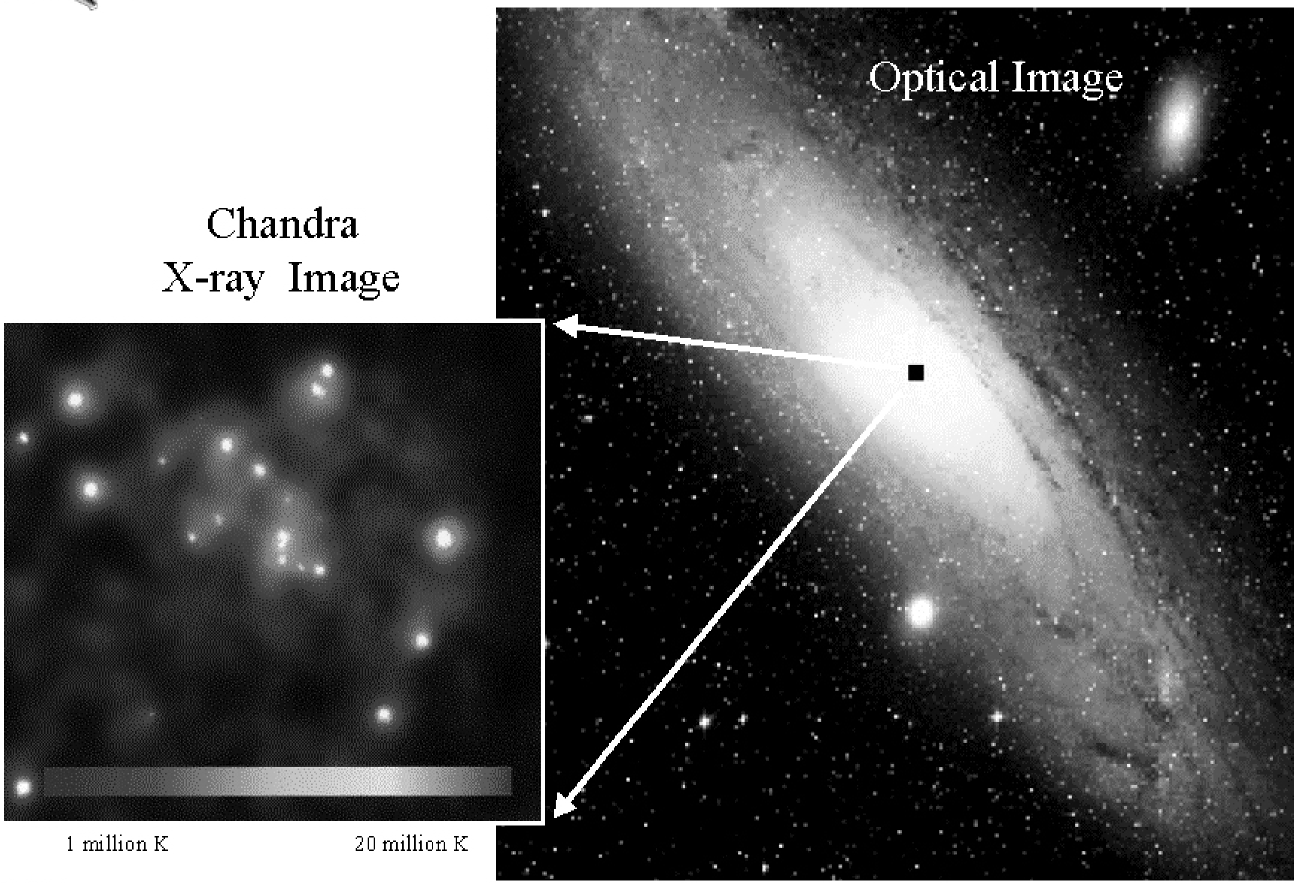


Resolved Image of Betelgeuse (HST)

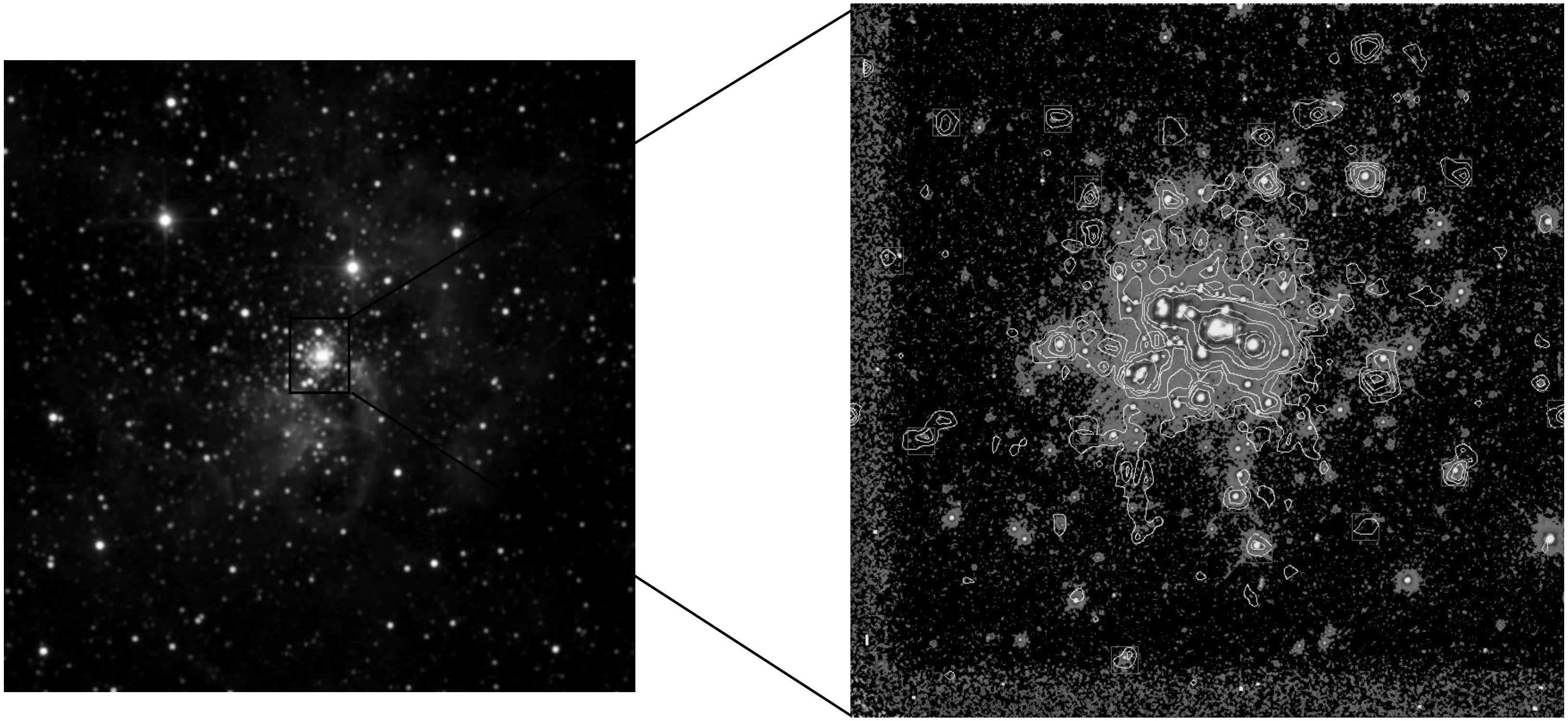
January 30, 2001

Mike Corcoran

M31: The Andromeda Galaxy



CXC



courtesy 2mass survey

NGC 3603 Open Cluster. 2 micron image (left); HST+Chandra (right)

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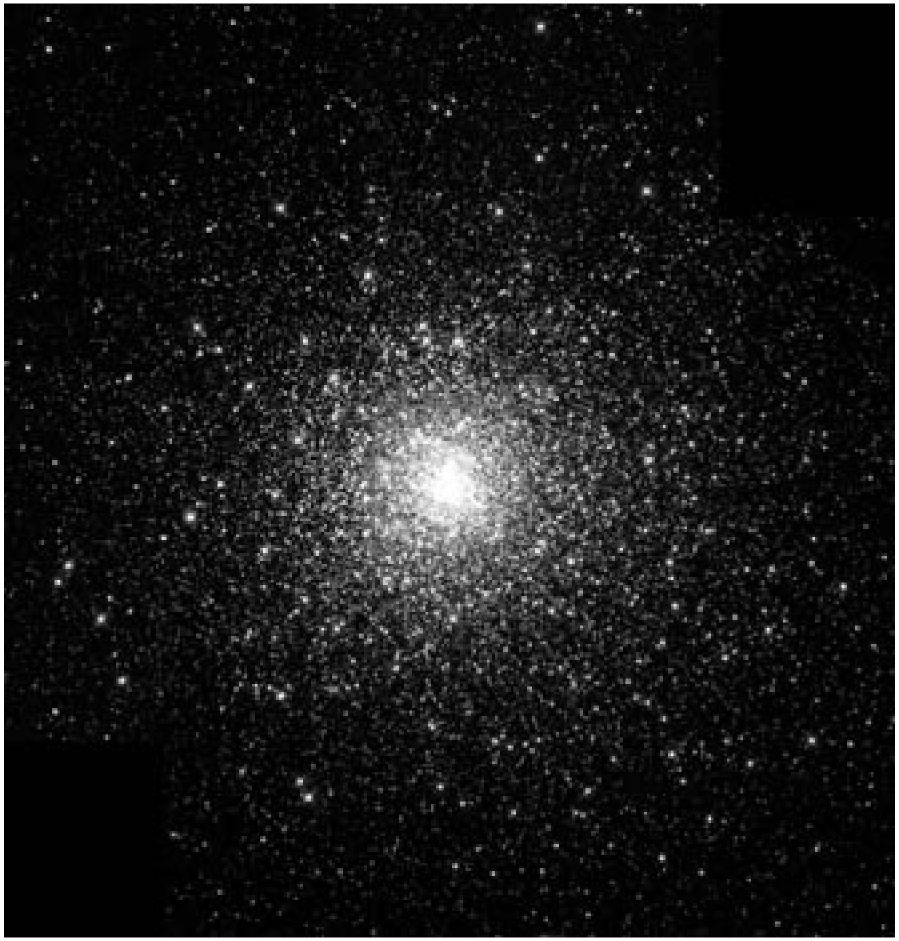

M80 (NGC 6093), one of the densest of the 147 known globular star clusters in the Milky Way galaxy

HST archive

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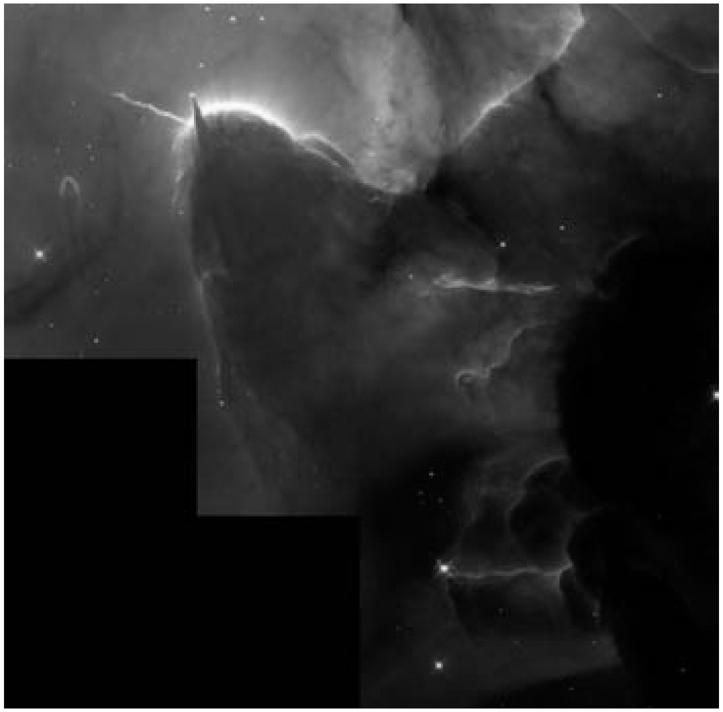

Young stars in the Trifid Nebula(HST)

Stellar jet from a young star (HST)

January 30, 2001

Mike Corcoran

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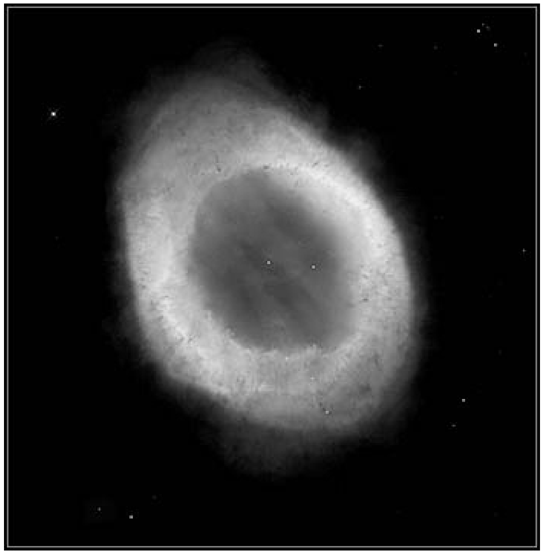
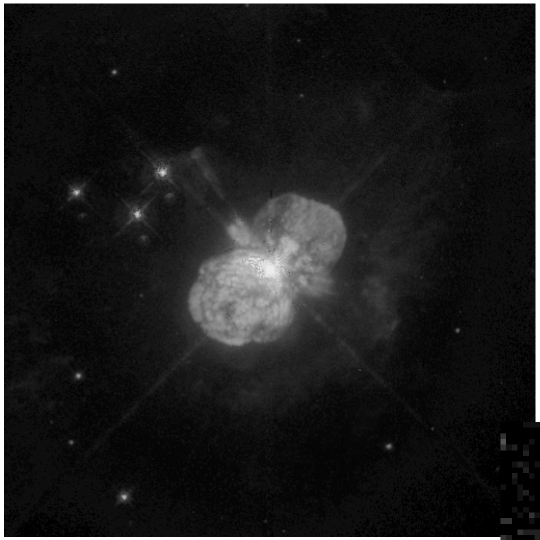
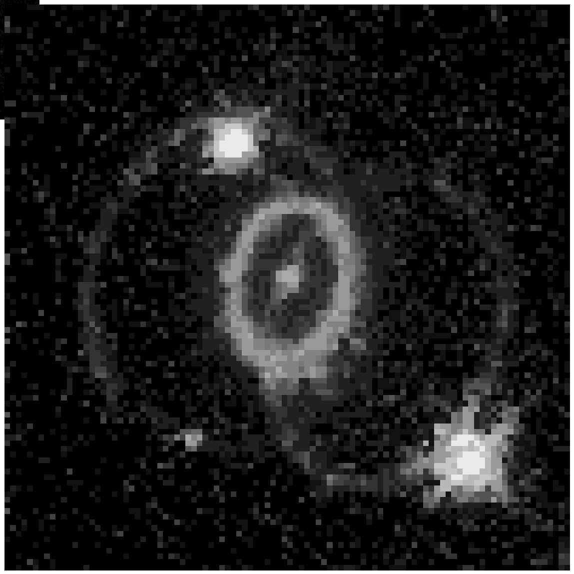


planetary nebulae: the Ring Nebula M57 (HST)



Eta Carinae (HST)



SN 1987A (HST)

Stellar Blowouts

January 30, 2001

Mike Corcoran

STAR: a self-gravitating object in hydrostatic and energy equilibrium which provides a stable source of radiant energy over long periods of time (10^6 - 10^8 years)

energy equilibrium: amount of energy produced = amount of energy lost

hydrostatic equilibrium: the gravitational force inward on every layer of the star is balanced by a pressure force outward

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Observables:

- Brightness
- Color
- Location (Right Ascension, Declination); (Galactic Longitude and Latitude); distance
- motion

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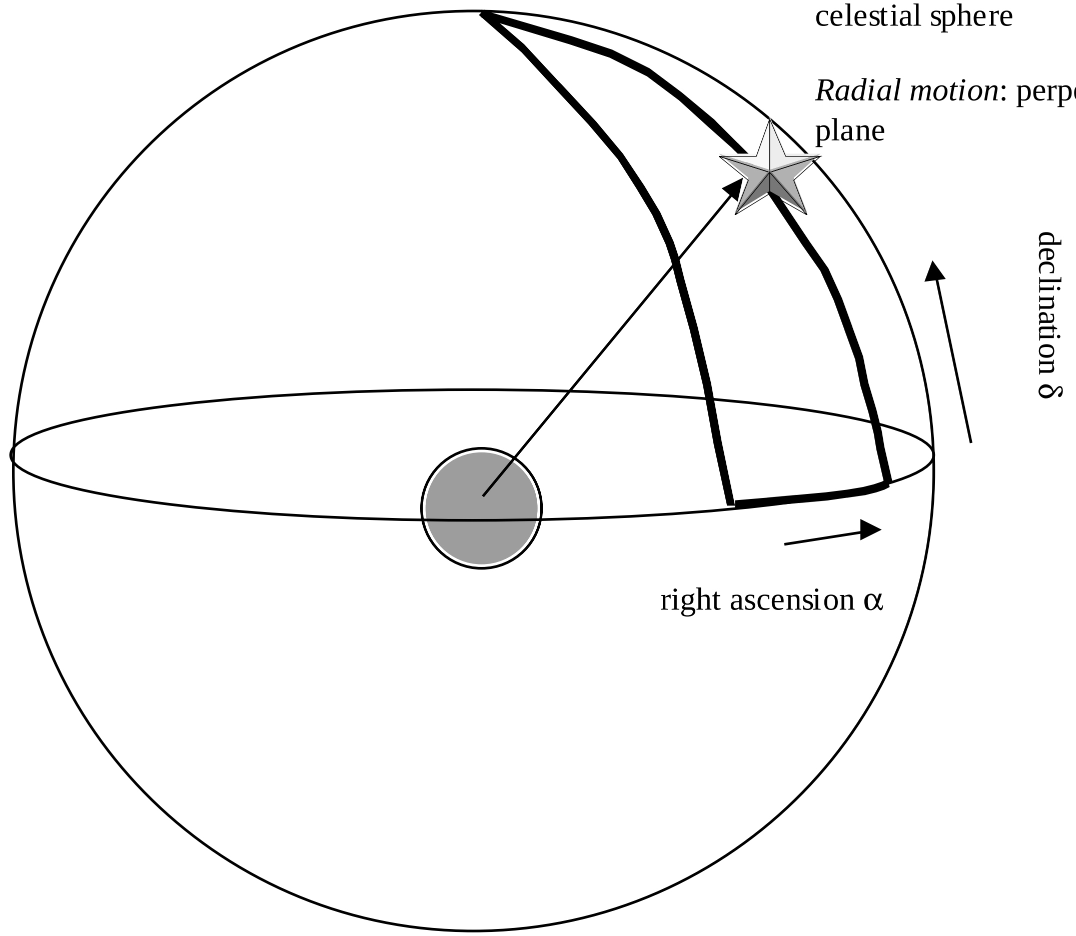

Locating Stars on the Celestial Sphere

January 30, 2001

Mike Corcoran

Observing Techniques:

- spectrophotometry: measure brightness as a function of stellar type, distance (generally not known), time, and wavelength/energy using a light gatherer (telescope) plus detector system (photometer + filters or disperser)

- Imaging spectrophotometry (photographic plate; ccd; etc).

- polarization: orientation of aspherical distribution of scatterers of EM radiation

Spectrophotometry:

• broad-band: use filters to selectively monitor EM radiation from star over a (generally broad) wavelength range, ex:
Johnson UBV
Stromgren ubvy
— generate relative stellar brightnesses in different filters: define stellar colors (U-B, B-V, etc)
— use of "standard stars"
Brightness of star measured in magnitudes:

$$m_1 - m_2 = -2.5 \log f_1/f_2$$

$m_1 - m_2$ is the observed magnitude difference between any 2 stars
f_1, f_2 are the respective stellar fluxes (in ergs/s/cm^2) at earth

Apparent Magnitude: represents how bright a star appears to be over some wavelength interval

Absolute Magnitude: represents the brightness of a star over some wavelength interval if that star were at a fixed distance of 10 pc (1pc = 3.26 lightyears) and if absorption were negligible

$$m_V - M_V = 5 \log (D/10)$$

m_V is the apparent visual magnitude of a star (corrected for absorption)

M_V is the absolute visual magnitude of a star

D = distance

• Stars appear fainter if they are at D > 10 pc (almost all stars are) since the flux f received at earth from a star is

$$f = L/(4\pi D^2)$$

where L = stellar luminosity (ergs/s)

•Stars also appear fainter due to absorption of starlight by gas and dust in the *interstellar medium*

$$m_V = M_V + 5 \log (D/10) + A_V$$

where

A_V = amount of visual extinction, in magnitudes

Absorption by the ISM makes starlight look fainter, and also REDDER

Reddening: color of star as it appears to be vs. the “true” color of the star. Scattering from the ISM more efficient at shorter wavelengths, so “blue” photons preferentially removed from starlight

usually expressed in terms of a *color index*

$$\underbrace{E(B\text{-}V)}_{\text{color excess}} = \underbrace{(B\text{-}V)}_{\text{observed color index}} - \underbrace{(B\text{-}V)_0}_{\text{Intrinsic color index}}$$

In general the color excess is related to the amount of extinction:

$$A_V = 3.2\ E(B\text{-}V)$$

The color excess E(B-V) is also related to the *column density* of absorbing material between earth and the star

$$N_H = 5.8 \times 10^{21}\ E(B-V)\ \text{atoms/cm}^2$$

where the column density N_H represents the number of atoms in a column of 1 cm^2 in cross section in the direction of the star, and is related to the number density of atoms by

$$N_H = \int n_e\, dZ$$

where n_e is the number density of atoms between earth and the star and the integration is taken along a line Z between the earth and the star.

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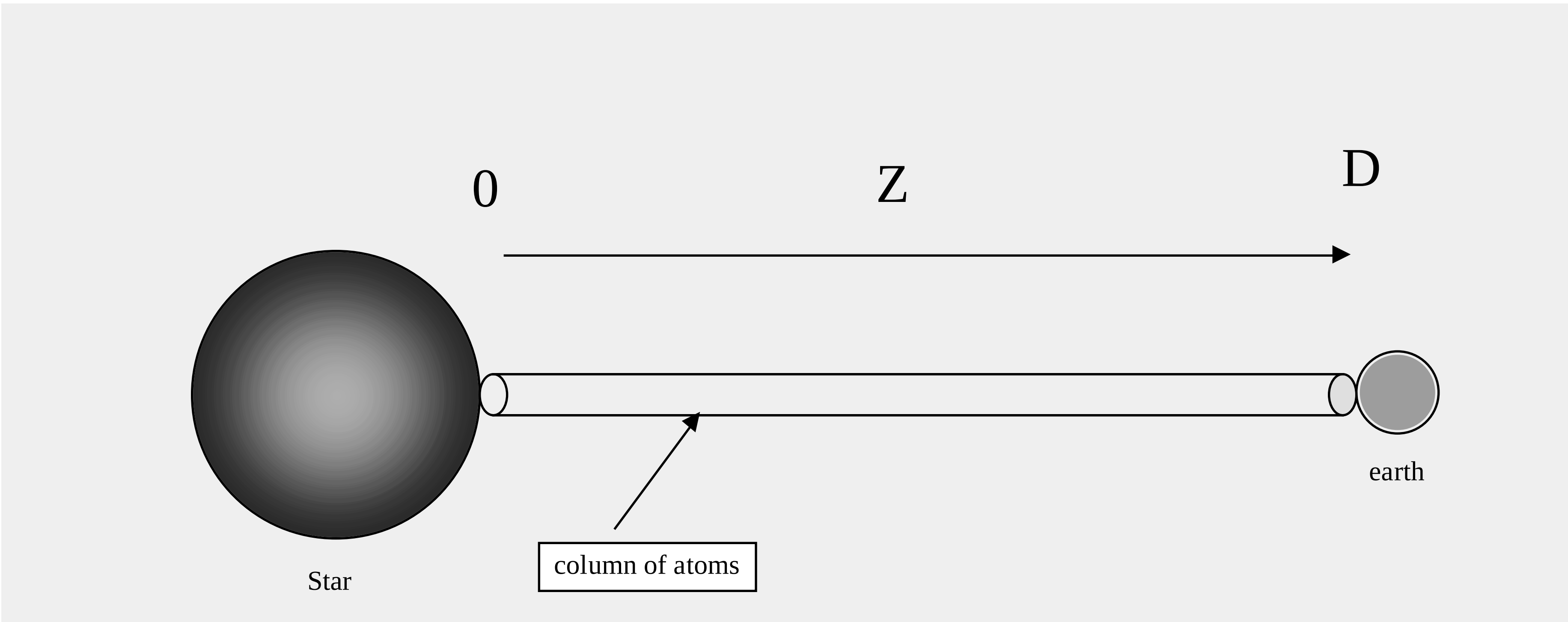

if n_e is constant with D, then

$$N_H = n_e D$$

Uses of broad-band spectrophotometry

- Monitor brightness/color changes of stars with time: stellar eclipses and ubiquity of binary star systems

- Determine brightnesses and colors for groups of stars, and plot them ==> Hertzsprung-Russell Diagram

HRD: first clue to stellar structure and evolution

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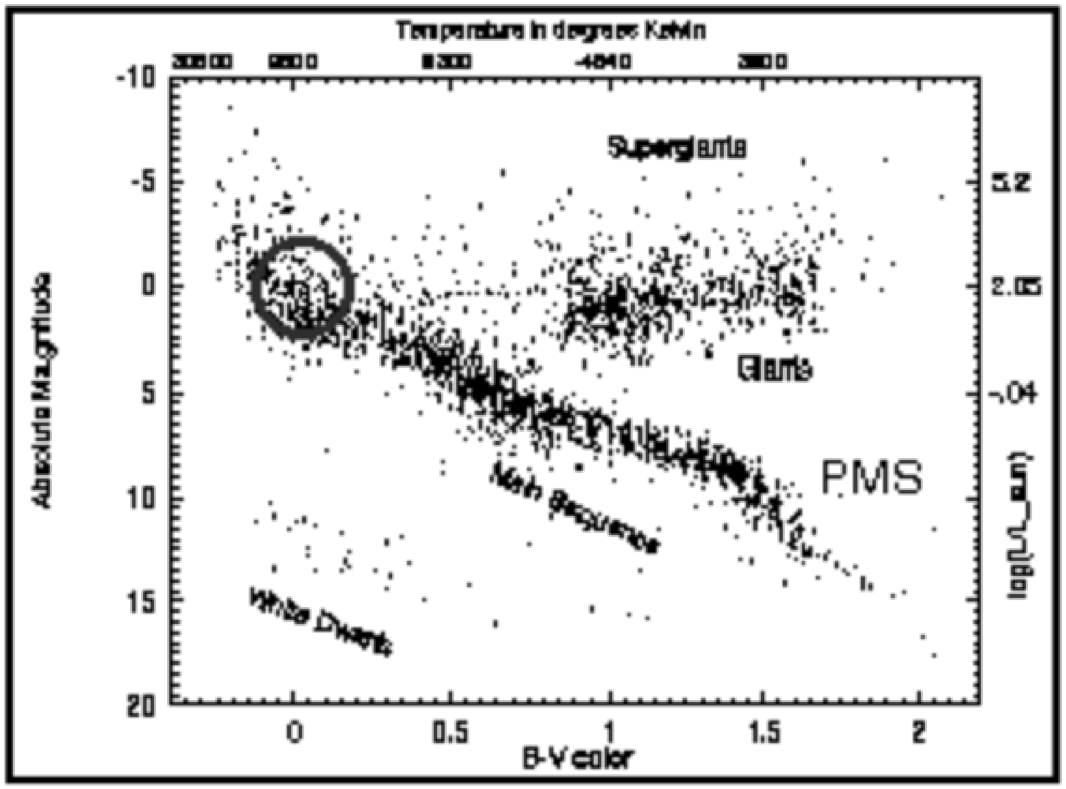
HR Diagram

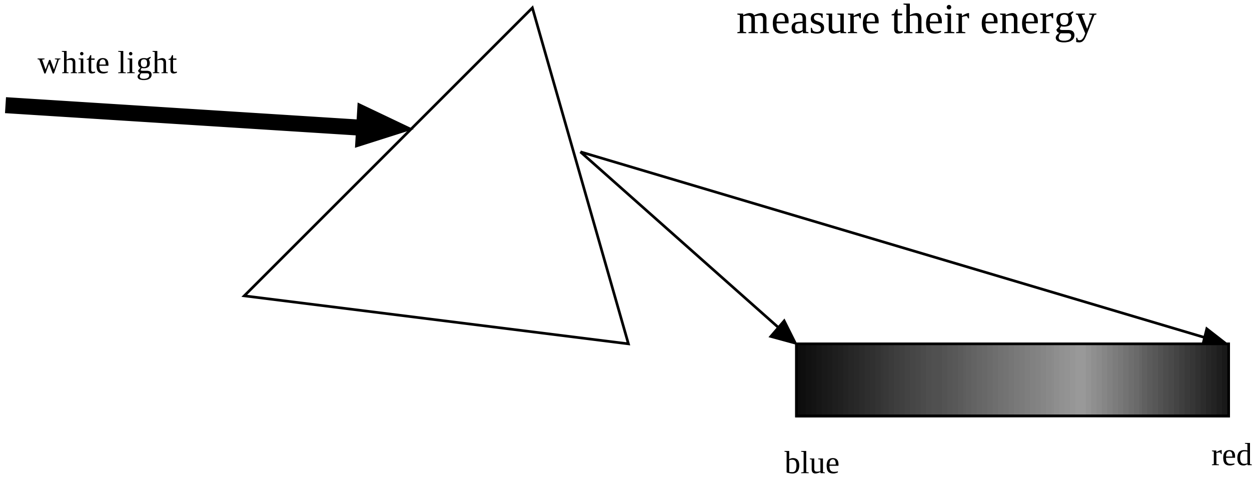


Narrow band Spectrophotometry and Spectral Analysis

- Broad-band colors provide useful but limited amount of information (relative and absolute brightnesses, temperature indicators, amount of absorption)
- Narrow band spectrophotometry (using very narrow filters) can provide even more information about the wavelength distribution of stellar radiation
- The most detailed amount of information is provided by spectral analysis (dispersing the stellar flux into its component wavelengths)

Dispersion using a prism or grating

Other techniques: count individual photons and measure their energy



Visible band spectral energy distribution

Continuum emission: unbroken distribution of emission over some wavelength range.

Hot solid objects radiate as black bodies, with SED described by Planck's law

$$B_\lambda(\mathrm{T}) = 2\,h\,c^2\,\lambda^{-5}\,\{e^{hc/\lambda kT} - 1\}^{-1}$$

is the amount of energy radiated by each cm^2 of the black body per second over each angstrom (Å) of wavelength

B_λ = specific intensity (Units: ergs cm^{-2} s^{-1} Å^{-1})

Wien's Law: Wavelength of maximum of emission inversely proportional to temperature:

$$\lambda_{max}\,T = 0.29\ \mathrm{cm\ K}$$

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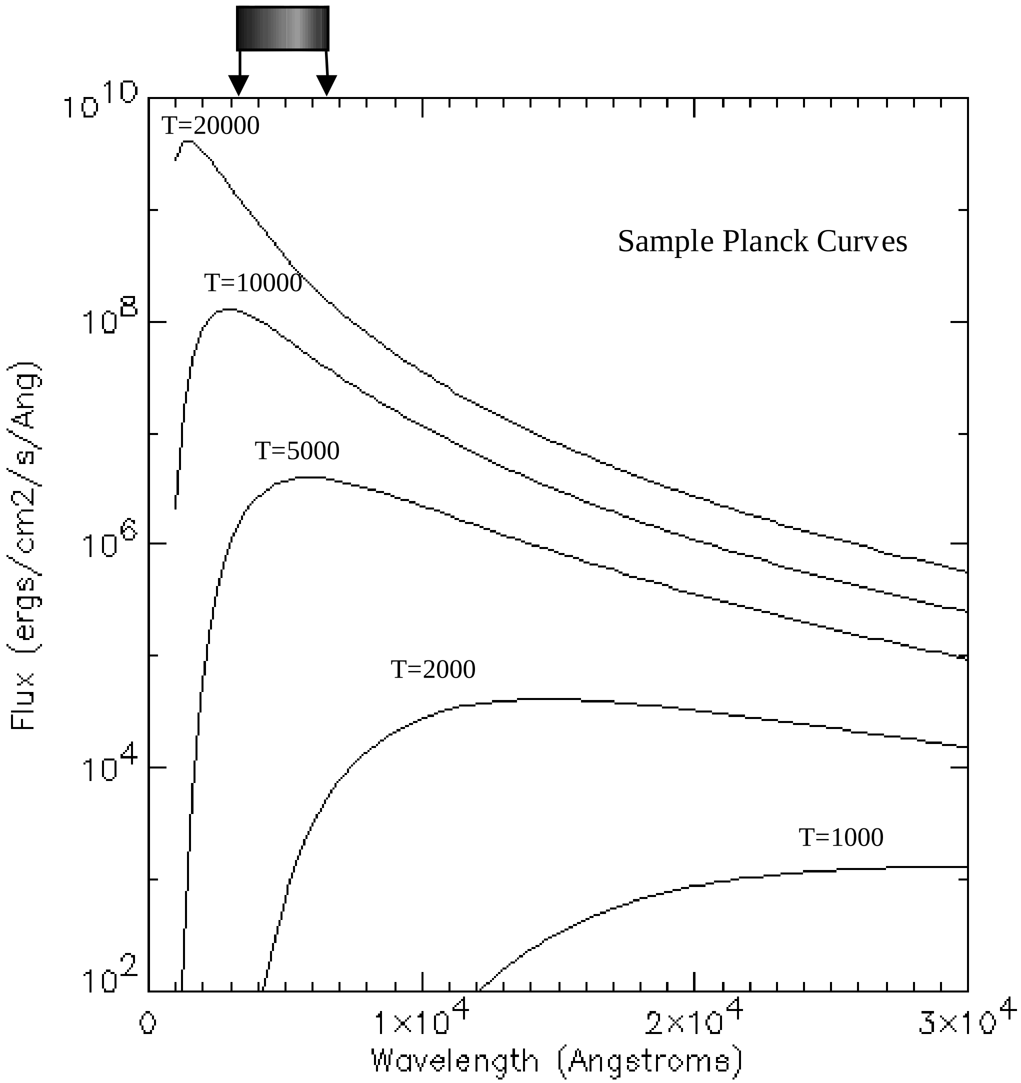
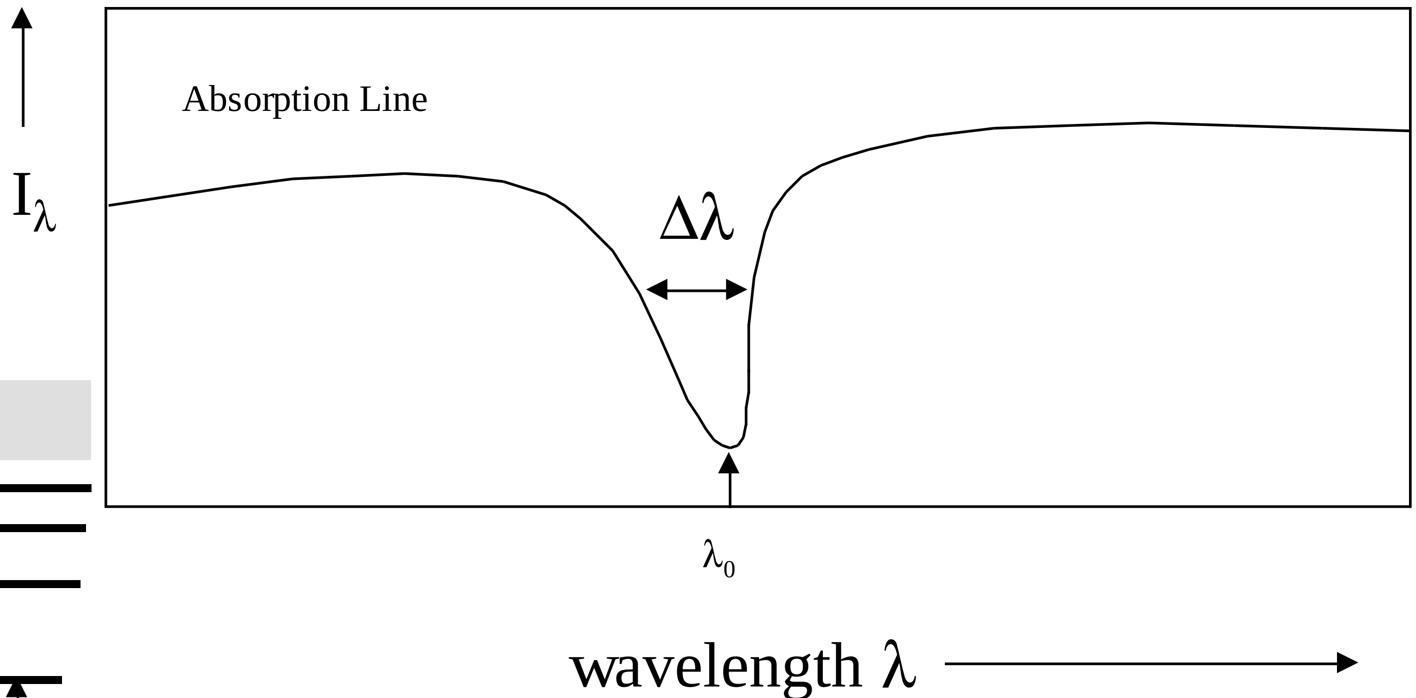
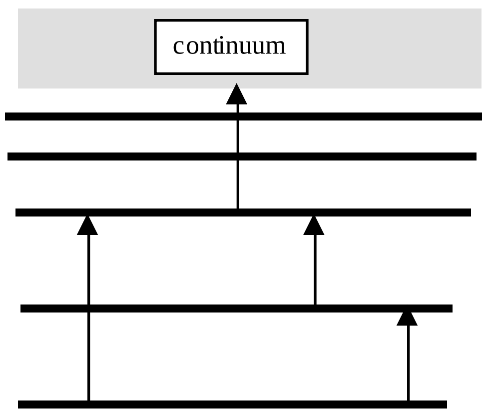
B_λ



Spectral Lines:





atomic energy levels

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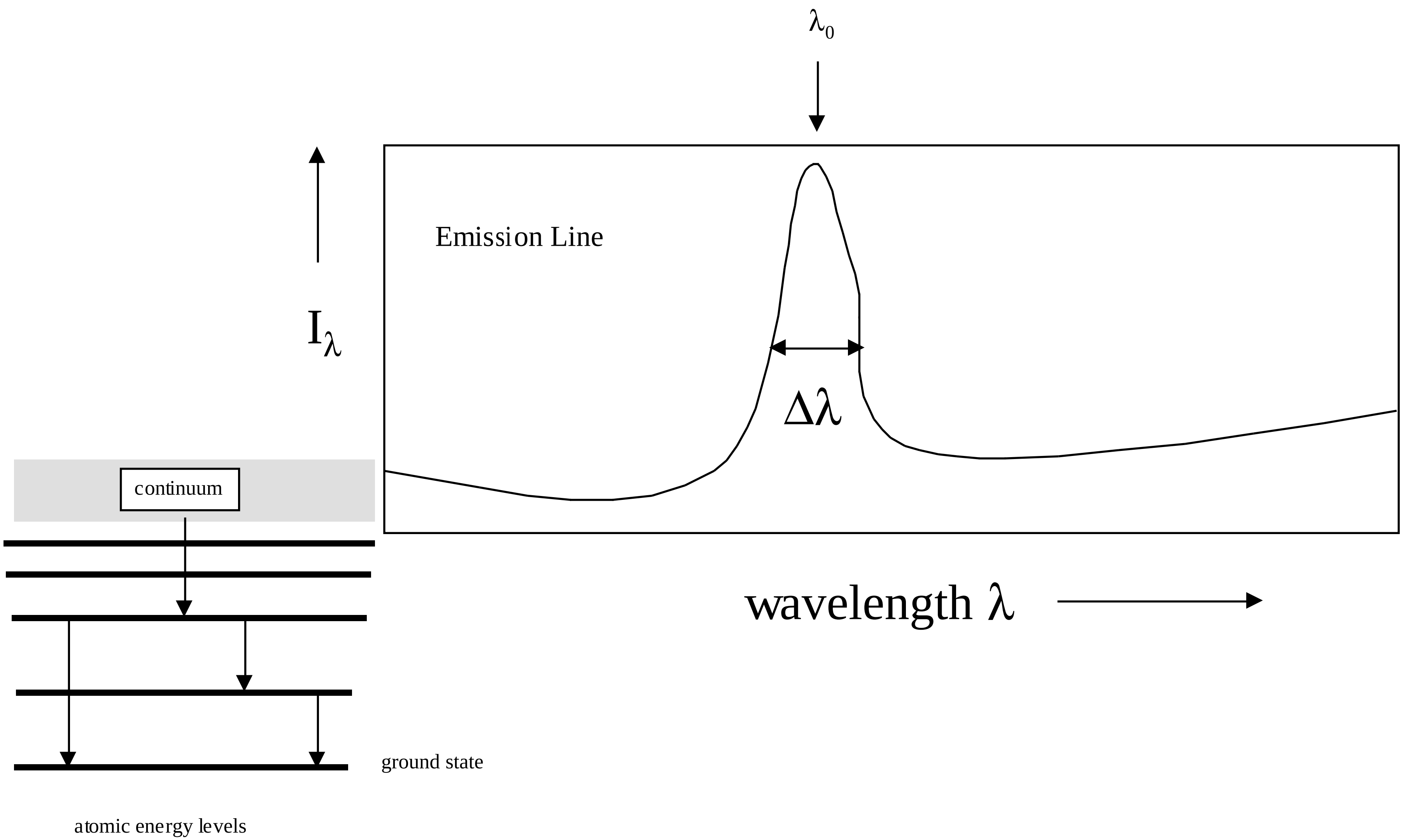

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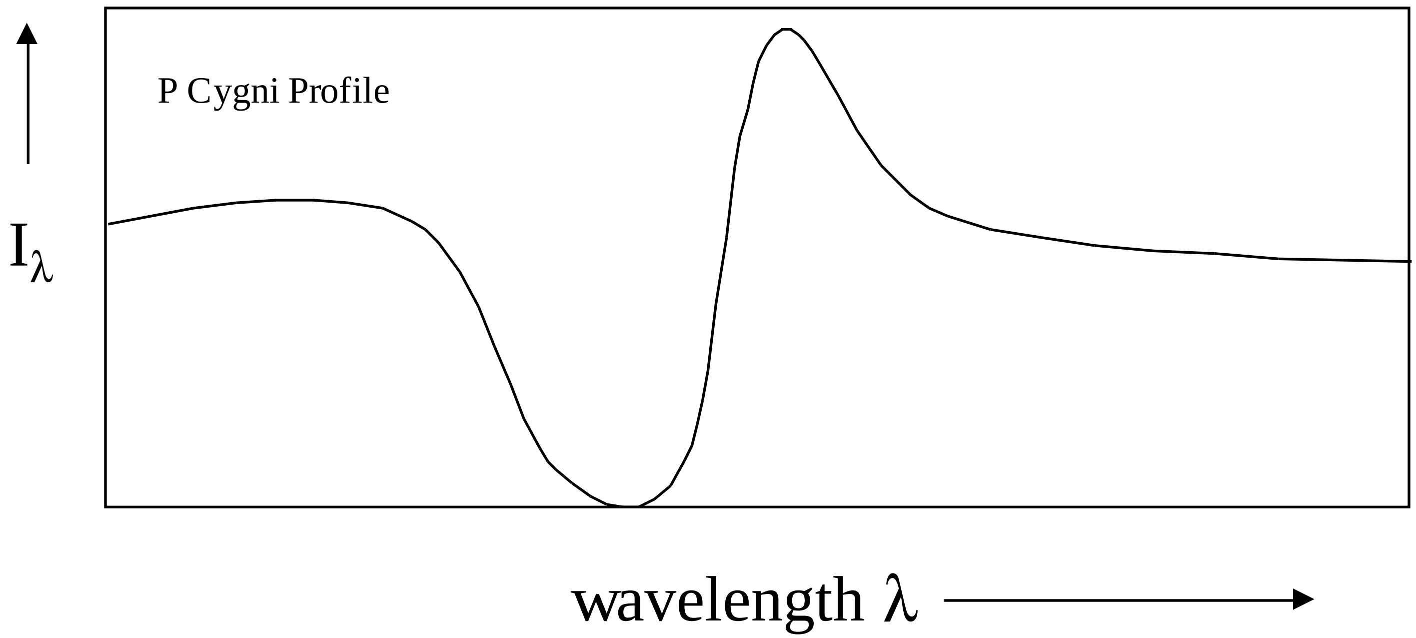
P Cygni Profile
I_λ
wavelength λ

Line Diagnostics:

- Centroids indicate element, ionization state (Abundances, temperatures)

- widths indicate broadening mechanism: eg, Doppler broadening, Zeeman broadening, pressure broadening (gas motions, dynamics, magnetic fields)